

The evaluation of healing patterns in surgically created circumferential gap defects around dental implants according to implant surface, defect width and defect morphology

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ABSTRACT

Purpose: The aim of this study was to evaluate the factors affecting healing patterns of surgically created circumferential gap defects around implants in dogs.

Materials and Methods: In four mongrel dogs, all mandibular premolars were extracted. After 8 weeks of healing periods, implants were submerged. According to the surface treatment, turned surface was designated as a group A and rough surface as a group B. In each dog, surgical defects on the left side were made with a customized tapered step drill and on the right with a customized paralleled drill. Groups were also divided according to the width of the coronal gaps: 1.0mm, 1.5mm, or 2.0mm. The dogs were sacrificed following 8 weeks and the specimens were analyzed histologically and histomorphometrically.

Results: During the postoperative period, healing was uneventful and implants were well-maintained. As the size of the coronal gap was increased, the amount of bone-to-implant contact was decreased. The bone healing was greater in rough surface implants compared to the turned ones. About the defect morphology, tapered shape showed much bone healing and direct bone to implant contact even in the smooth surface implants.

Conclusion: Healing of the circumferential defect around dental implant is influenced by the implant surface, defect width and the morphology of the defect. When using rough surface implants, circumferential gap defects within 2 mm do not need any kinds of regenerative procedures and the healing appeared to be faster in the tapered defect morphology than the paralleled one. (*J Korean Acad Periodontol 2008;38:385-394*)

KEY WORDS: defect width; defect morphology; implant surface; gap.

Introduction

There has been increasing interest in placement of a dental implant into a fresh extraction socket and many authors have tried to improve clinical efficacy on immediate implant in human clinical studies¹⁻¹⁵. The advantages of immediate implantation are as follows: total treatment time can be shortened; the horizontal and vertical levels of the residual socket wall

can be more easily preserved than with the delayed implantation; positioning of the implant is optimized; the need for additional surgeries like bone augmentation is lessened; and the healing potential of residual periodontal ligament cells is helpful for successful osseointegration^{2,3,8,9}. On the other hand, coronal gaps made around the implants placed immediately into fresh extraction sockets and the lack of soft tissue that makes it difficult to maintain a primary closure of the surgical site can be problematic^{6,10-12}.

Several studies have been published the relationship between gap width and healing pattern around immediate implants¹⁶⁻²⁴. Carlsson et al.¹⁶ used titanium implants with initial gap widths of 0.00, 0.35, and 0.85mm to find out that there was no osseointegration

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to be shown histologically when the gap between bone and implant was larger than 0.35mm. Knox et al.¹⁷⁾ proved that the gaps larger than 1 mm resulted in smaller amount of direct bone to implant contact. In their clinical study, Thomas et al.¹⁸⁾ demonstrated that there was no need of membrane at the gap less than 0.5mm, while no integration between bone and implant could be observed at the width more than 4mm. Akimoto et al.¹⁹⁾ studied a smooth surface implant placed in the surgically created bone defect sites after tooth extraction in dog experimental model. Bone regeneration was found in gap width more than 0.5mm clinically, but histologically there was no direct contact between bone and implant.

Botticelli et al.^{20,21)} suggested that implant surface characteristics can affect the healing pattern of gap defect around implant. They used rough surface implant (SLA) in dogs by creating bone defects with 1 to 1.25mm gaps and barrier membranes were used to cover the coronal defects. They suggested that the gaps were healed by appositional bone growth from the lateral and apical bone walls of the defects. More recently, they also compared bone healing around the implants with turned or rough surface topographies placed in self-contained defects using either a submerged or non-submerged technique and suggested that the rough surface showed superior healing pattern than the turned one²²⁾.

The actual shape of the fresh extraction socket is approximately conical, but the paralleled defects made sur-

gically has been used mostly in the previous study models. Creating tapered defects are necessary to understand the healing pattern of natural extraction socket.

The aims of this study were to evaluate and compare the healing patterns according to the implant surface characteristics, gap width and gap morphology around the implants.

Materials and methods

1. Animals

Four male mongrel dogs with 18 to 24 months old and weighing about 30kg were chosen. They had intact dentitions and healthy periodontium. Animal selection, management, preparation and surgical protocol were followed by the routine procedures approved by the Animal Care and Use Committee, Yonsei Medical Center, Seoul, Korea.

2. Experimental Design

Animals were divided into the group A those with turned surface implants and the group B, rough (resorbable blast media ; RBM) surface implants.

The defects in the left side were made surgically with a customized tapered step drill and those in right with customized paralleled drill. Groups were also divided according to the width of the coronal gaps: 1.0mm, 1.5mm, 2.0mm (Fig. 1, Fig. 2a, 2b).

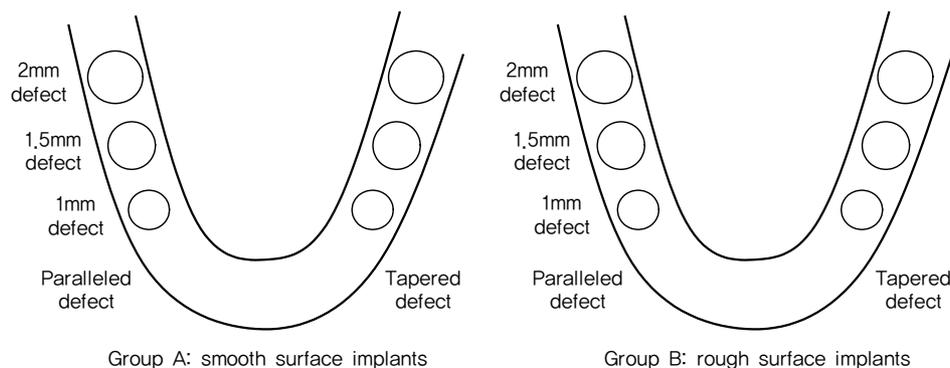


Figure 1. Schematic drawing of experimental design.

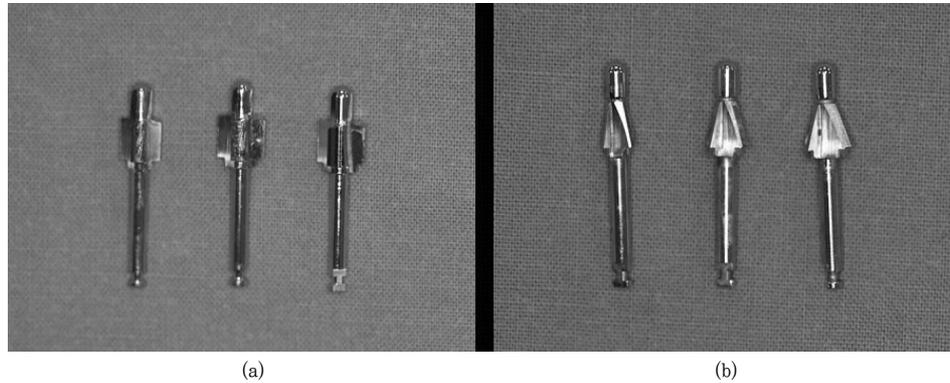


Figure 2. Customized drills

- a. Stepped paralleled drills, from the left, a 5.5-mm diameter drill for the 1.0-mm gap defect, a 6.5-mm diameter drill for the 1.5-mm gap defect and a 7.5-mm diameter drill for the 2.0-mm gap defect are represented, respectively. The length of the drill is 5mm.*
- b. Stepped tapered drills, from the left, a 5.5-mm diameter drill for the 1.0-mm gap defect, a 6.5-mm diameter drill for the 1.5-mm gap defect and a 7.5-mm diameter drill for the 2.0-mm gap defect are represented, respectively. The length of the drill is 5mm.*

3. Surgical protocol

Teeth were extracted under general anesthesia under sterile conditions in an operating room using Atropine 0.05 mg/kg SQ, xylazine (Rompun[®], Bayer Korea, Seoul, Korea) 2 mg/kg, and ketamine hydrochloride (Ketalar[®], Yuhan Co., Seoul, Korea) of 10 mg/kg IV. Dogs were placed on a heating pad, intubated, administered 2% enflurane, and monitored with an electrocardiogram. After disinfecting the surgical site, 2% lidocaine HCl with epinephrine 1:100,000 (Kwangmyung Pharm., Seoul, Korea) was administered by infiltration. Crevicular incisions were made and all premolars were carefully extracted. Prior to extraction, P2-P4 were sectioned to avoid tooth fracture. Flap was sutured with 5-0 resorbable suture material (Polyglactin 910 braided absorbable suture, Ethicon, Johnson & Johnson Int., Edinburgh, UK) by the vertical mattress suture technique. On the day of surgery, the dogs received 10 mg/kg IV of the antibiotics Cefazoline.

The implants (Restore[®], Lifecore, USA) were placed after a healing period of 8 weeks under the same surgical conditions as those for tooth extraction. A crestal incision was made to preserve keratinized tissue and mucoperiosteal flap was carefully reflected on the buccal and lingual aspect. The edentulous ridge was carefully flattened with a surgical bur and irrigated with sterile saline. Implant osteotomy was performed at 800 rpm under chilled saline irrigation and circumferential defects of 1.0mm, 1.5mm and 2.0mm gaps with 5mm defect depth were created surgically with a customized paralleled step drill, and same procedure was done on the left side of mandible using a customized tapered step drill. Implant placement was made without tapping to obtain good initial stability. Turned surface implants in Group A and rough RBM surface implants in Group B were used. Three submerged type implants (3.5mm diameter, 10.0mm length) were placed on the right side of the mandible (Fig. 3).

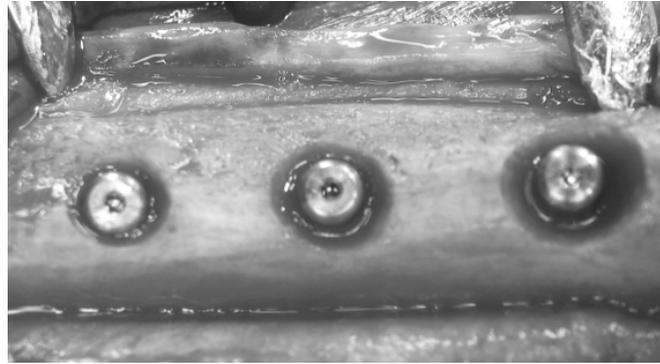


Figure 3. Clinical photograph representing the experimental design; from the left, 1.0mm, 1.5mm and 2.0mm gaps were prepared, respectively.

Flaps were closed with 5-0 resorbable suture materials and implants were submerged. Post-operative care was similar as that for tooth extraction. Sutures were removed after 7 to 10 days and a soft diet was provided throughout the study period.

Dogs were sacrificed 8 weeks after surgery. Euthanasia was performed by anesthesia drug overdose. Block sections including segments with implants were preserved and fixed in 10% neutral buffered formalin.

The specimens were dehydrated in ethanol, embedded in methacrylate, and sectioned in the mesio-distal plane using a diamond saw (Exakt®, Apparatebau, Norderstedt, Germany). From each implant site, the central section was reduced to a final thickness of about 20 μ m by microgrinding and polishing with a cutting-grinding device (Exakt®, Apparatebau, Norderstedt, Germany). The sections were stained in hematoxyline-eosin.

4. Histologic analysis

General histologic findings were observed with a stereoscope (LEICA MZFLIII, LEICA, WETZLAR, Germany) and microscope. After conventional microscopic examinations, computer-assisted histometric measurements were obtained using an automated image analysis system (Image-Pro Plus®, Media

Cybernetics, Silver Spring M.D., USA) coupled with a video camera mounted on a light microscope (LEICA DM-LB, LEICA, WETZLAR, Germany). The measuring points were as follows.

- 1) distance (mm) from the implant margin to the most coronal level of contact between bone and implant
- 2) bone to implant contact percentage (BIC%) in the coronal 5mm of the implant

Results

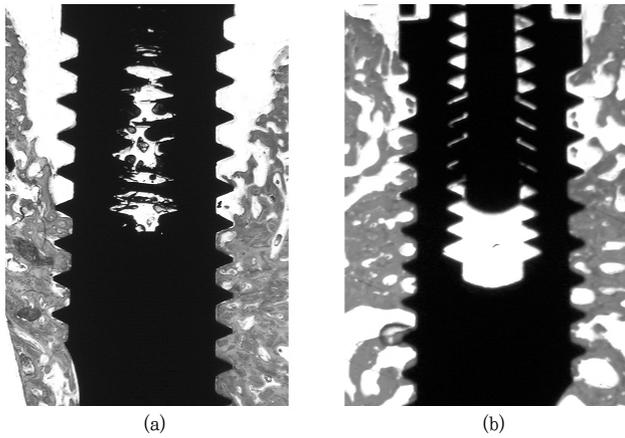
1. Clinical findings

During the postoperative periods, healing was uneventful and implants were well-maintained. There were no signs of inflammation observed in the mucosa adjacent to the implants.

2. Histologic findings

1) Implant surface

The healing of rough surface implants was superior to smooth surface implants. Wedge shaped defect in coronal portion was found in the 2mm width of parallel defect in group A, when there was good bone-to-implant contact in Group B (Fig. 4a, 4b).



2) Defect width

More remaining area which was not filled with bone was found at the larger width of the defect around the implant. There was a remaining wedge shaped defect in 2mm tapered gap in group A (Fig. 5a, 5b).

3) Defect morphology

Most of the tapered defects showed good bone filling compared to the paralleled defects. In 1.0mm gap of Group A, good bone fill was found in the tapered defect when there was no direct bone-to-implant contact in paralleled one (Fig. 6a, 6b).

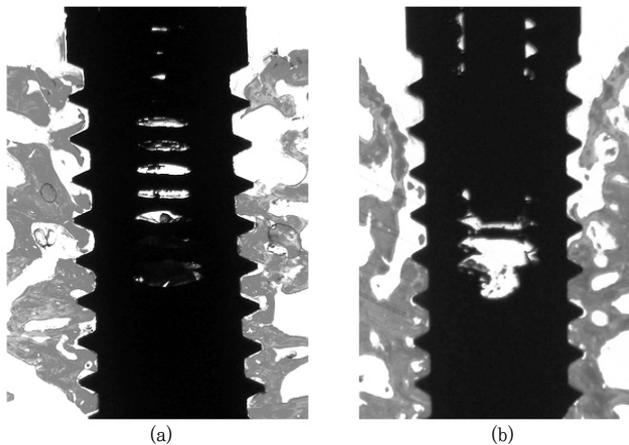


Figure 5. Histologic view of group A (turned surface) in tapered defect with gap defect width of 1mm (a) and with gap defect width of 2mm (b), H-E stain, magnification X8.

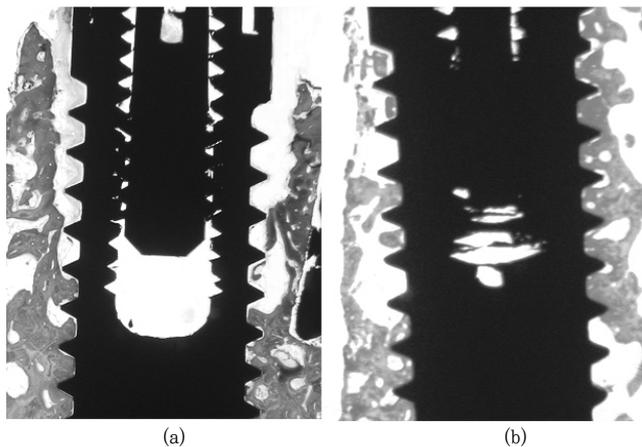


Figure 6. Histologic view of group A (turned surface) in 1 mm gap defect with tapered defect morphology (a) and with paralleled defect morphology (b), H-E stain, magnification X8.

Table 1. Distance (mm) from the implant margin to the most coronal level of contact between bone and implant (N=2)

group \ defect	Paralleled defect			Tapered defect		
	1.0mm	1.5mm	2.0mm	1.0mm	1.5mm	2.0mm
Group A	3.05	3.52	3.99	0.28	1.50	2.05
Group B	0.65	1.75	1.75	0	0	0.95

Mean values are shown in this table.

N : number of the dogs used in each group (Group A, Group B)

Group A : turned implant surface group

Group B : rough implant surface group

Table 2. Bone to implant contact percentage (BIC%) in the coronal 5mm of the implant (N=2)

group \ defect	Paralleled defect			Tapered defect		
	1.0mm	1.5mm	2.0mm	1.0mm	1.5mm	2.0mm
Group A	8.9	5.2	2.6	34.2	28.7	10.5
Group B	28.7	25.2	10.7	42.7	41.5	27.4

Mean values are shown in this table.

N : number of the dogs used in each group (Group A, Group B)

Group A : turned implant surface

Group B : rough implant surface

3. Histomorphometric analysis

1) Distance (mm) from the implant margin to the most coronal level of contact between bone and implant

With increasing size of the coronal gap, the distance tended to be greater. Regarding the implant surface characteristics, greater distance was shown in the turned implant than the rough one. In defect morphology, paralleled shape demonstrated greater distance than the tapered one (Table 1).

2) Bone to implant contact percentage (BIC%) in the coronal 5mm of the implant

With decreasing size of coronal gap, bone to implant contact tended to be greater. Regarding the implant surface characteristics, rough surface showed greater bone to implant contact than turned surface implant. In defect morphology, tapered shape showed greater bone to implant contact than paralleled one (Table 2).

Discussion

The immediate implant placement technique was introduced to shorten the rehabilitation periods and researches have been carried out to provide the theoretical backgrounds. There are many methods introduced to overcome the coronal gap associated with immediate implant^{3,5,6,10-12,15,23-25)} however, the critical size of defect allowing spontaneous healing has yet to be determined. To make the treatment procedure more simplified and save the time for treatment benefiting both patient and practitioner, effort to figure out the critical size is of importance. Besides defect width, implant surface and defect morphology can influence the healing of circumferential gap defect around implants.

About defect width, Akimoto et al.¹⁹⁾ used dog model to evaluate the bone fill that occurred in defects adjacent to implants designed with machined surface. Implants were placed in simulated extraction sockets that had been prepared in such a way that gaps between 0.5 and 1.4mm separated the implant surface

and the bone. A clinical examination was performed after 12 weeks of healing showing that all the defects, independent of size, had healed properly. Histologic evaluations in biopsies obtained from the different defect sites, however, revealed that there were consistent certain distances between the marginal borders of the implants and the most coronal levels of bone-to-implant contact. Further, this distance varied with the initial size of the defect, so that when the defect was wider the distance between the rim of the implant and the level of bone to implant contact became longer. In the present study, the 2mm defect width tended to make more wide and deep wedge shaped coronal defect than 1mm defect width. It suggests that the greater defect width will need more healing time to fill the bone defect.

To mention the implant surface characteristics in the present study, rough surface implants with resorbable blast media (RBM) were used. To obtain RBM surface, a machined titanium implant was blasted with calcium phosphate ceramic and then passivated to completely remove the residual media. The surface roughness ranged from 3.09 ± 0.38 microns and micro-pit diameter ranged from 5 to 10 microns.

Osteoblasts may lay down bone on the old bone surface or on the implant surface itself. Davies²⁶⁾ suggested that there are two different phenomena by which bone can become juxtaposed to an implant surface: distance and contact osteogenesis. Distance osteogenesis is that in which new bone is formed on the surfaces of bone in the peri-implant site through appositional growth and contact osteogenesis or osteoconduction is that in which de novo bone formation occurs directly on the implant surface. He suggested that implant with roughened surface, as opposed to implant with smooth surface, may promote osteoconduction by both increasing available surface area for fibrin attachment and providing surface features with which fibrin could become entangled.

More recently, Davies²⁷⁾ also explained that the im-

plant surface design will play an important role in the fibrin retention. Fibrin retention is so critical to osteogenic cell migration to the implant surface. Bone cells will reach the implant surface by migration through fibrin, and these cells will then be available to synthesize de novo bone on the implant surface itself.

Akimoto¹⁹⁾ studied marginal bone defects of varying dimensions that occurred following placement of implants with turned surface failed to heal with proper osseointegration. In contrast, similar experiments²¹⁾ was done with rough surface implants demonstrated that marginal bone defects were resolved by de novo formation of hard tissue. Botticelli et al.²²⁾ compared bone healing at implants with turned or rough surface in self-contained defects using dogs. After 4 months of healing, the marginal defects around rough surface implants exhibited substantial bone fill and a high degree of osseointegration, but healing at turned implants was characterized by incomplete bone fill and the presence of a connective tissue zone between the implant and the newly formed bone.

Present study showed that bone healing was superior in bone defects adjacent to implants with a rough compared to smooth surface implants, and it is similar to a previous study²²⁾. The reason can be explained that the defect healing of rough surface implants is occurred by combination of contact osteogenesis and distance osteogenesis, but healing of smooth surface implants is done only by distance osteogenesis. Therefore, the remodeling of defect will be faster in the rough than smooth surface implants.

In defect morphology, several studies have been published the relationship between gap width and healing pattern around implants in immediate implantation. Most of these studies used a paralleled defect model. However a shape of fresh extraction socket is a conical, so this study used a tapered stepped drill to reproduce an actual extraction socket. In this study, most of tapered defect were found good

bone filling rather than paralleled defect. In taped defect, there was found good bone fill in the 1.0mm gap of group A. However, in the paralleled defect, no direct bone-to-implant contact was found in the 1.0 mm gap of group A. Bone healing of paralleled defect was similar to findings reported by Akimoto¹⁹⁾, but tapered defect was different. This can be explained that a lateral wall at defect base is closer in tapered defect than paralleled defect. That means appositional bone growth occurred faster in tapered defect than paralleled defect.

Botticelli et al.²¹⁾ explained bone-to-implant contact was first established in the apical portion of the gap. This new bone tissue was in the coronal direction continuous with a dense, non-mineralized implant-attached soft tissue which, over time, also became mineralized and, hence, the height of the zone of bone-to-implant contact was increased.

Therefore, it can be concluded that healing of circumferential gap defects around implants is influenced by the implant surface, defect width, defect morphology. If using rough surface implants, circumferential gap defect within 2mm does not need any kind of regenerative procedure, and tapered defect morphology showed faster healing than paralleled defect morphology.

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